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Energy Procedia 50 (2014) 105 – 112

Energy Procedia

The International Conference on Technologies and Materials for Renewable Energy, Environment and Sustainability, TMREES14

Energy analysis of single effect absorption chiller (LiBr/H_2O) in an industrial manufacturing of detergent

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Abstract

The objective of this study is related to an absorption refrigeration system operating in an industrial manufacturing of detergent (Henkel Algeria).In fact detergent manufacturing requires a large amounts of vapor where the possibility of use it as a thermal energy in the absorption refrigeration system.The dual use of steam on the one hand as an input in the production of detergents, and also as thermal energy supplied to the absorption refrigeration system has a dual objective simultaneously characterizing energy saving and environmental protection. The tested machine met the assumptions that we have developed at least before his sudden stop due to an increase in pressure which we describe in this work. We have established the comparison of calculated values with several experimental measurements, which allows saying that the simulation model describes satisfactorily the behaviour of the refrigerating machine before failure.

Selection and peer-review under responsibility of the Euro-Mediterranean Institute for Sustainable Development (EUMISD)

Keywords: absorption, lithium bromide-water, energy, measure, simulation, performance, detergent;

Nomenclature

COP	coefficient of performance	Q	heat transfer rate (KW)
FR	flow ratio	W	work (KW)
h	enthalpy (KJ/Kg)	X	concentration of LiBr–water solution (%)
m	mass flow rate (Kg/s)	ΔX	range of degassing

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1876-6102

Selection and peer-review under responsibility of the Euro-Mediterranean Institute for Sustainable Development (EUMISD)

doi:10.1016/j.egypro.2014.06.013

1. Introduction

The ability to produce cold by direct or indirect primary sources, including renewable energy and industrial waste, notably natural gas, given opportunity to the absorption machines for the production of cooling water in chemical and food industry, the thermal power is commonly derived from industrial waste heat, renewable energy sources which do not cause ozone depletion as working fluid [1, 2] practically unknown for a century [3], The interest in recent years to these systems is related firstly to their ecological characteristics as not using CFC and HCFC refrigerants, various countries wish to find a solution to the problems of overload power grids during the warm seasons, problems caused by high power industrial chillers. Many literatures concerning these machines are available both theoretically and experimentally [4, 5].Analysis of the generator temperature in solar powered ($LiBr/H_2O$) system have been reported by Prasad [6], Prasad et al [7], alizadeh et al [8] and shiran et al [9]. Our study examines the case of an absorption refrigeration machine ($LiBr$ / H_2O) for cooling of a chemical reactor who ensures the production of the active ingredient, the chemical reaction (exothermic) named sulfonation performed in a multitubular film reactor to requires a large amount of cold, in the form of cooling water[10], to obtain a complete reaction. For this we collected a large amount of experimental data. The comparison of calculated values with several experimental measurements identified during operation of the absorption refrigeration machine allows that the simulation model established describes satisfactorily the behaviour of the refrigerating machine. The influence of the temperature of the hot source is predominant. It is obvious that much of the loss occurs in the heat exchangers, which is why the optimization of temperatures in the component elements of the machine was the purpose of the study on the basis of temperatures in all the heat exchangers. We propose an optimization model based on the influence of temperature and heat of the heat exchangers (generator / condenser, absorber / evaporator exchanger solution) on the performance to achieve better efficiency.

2. System description

The hot vapor is pumped to the generator to separate the refrigerant from the absorbent, then the superheated refrigerant is condensed in the condenser by the cold water of the cooling tower, water follows through the expansion valve and arrived to the evaporator to produce cold required. The vapor is lead to the absorber where it is absorbed by the rich solution coming from the generator; finally the rich solution is pumped to the generator via a heat exchanger. This cycle operates at low pressure to evaporate water at low temperatures. Fig. 1 shows the schematic diagram of the solar lithium bromide–water absorption cooling system. The absorption machine represented by Fig.2 is a kind CARRIER 16JB is installed at the production unit of Henkel detergent.

3. Thermodynamic analysis

For this part we established a thermodynamic analysis of the single-effect machine with a heat exchanger operating with the pair ($H_2O/LiBr$). Figure 01 presents these basic elements.

We adopt the following assumptions [11].

- There is saturated refrigerant at the condenser and evaporator outlets.
- There is no departure of chemical substances from the cycle to the environment.
- The kinetic and potential energy effects are neglected.
- The refrigerant (water) at the outlet of the condenser is saturated liquid and vapour.
- The Lithium bromide solution at the absorber outlet is a strong solution and it is at the absorber temperature.
- The outlet temperatures from the absorber and from generators correspond to equilibrium conditions of the mixing and separation respectively.
- Pressure losses in the pipelines and all heat exchangers are negligible.
- Heat exchange between the system and surroundings, other than in that prescribed by heat transfer at the generator, evaporator, condenser and absorber, does not occur.

At the absorber, two mass balances can be made:

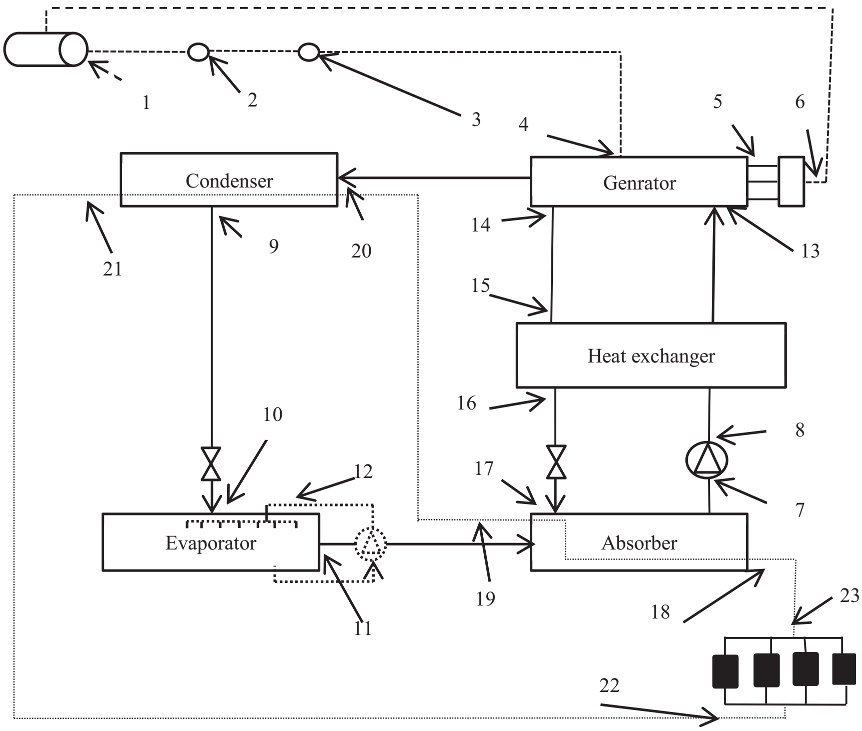

Fig.1. The schematic illustration of solar single effect absorption cooling system and different points of measure.

Fig. 2. Machine type CARRIER 16JB (unit Henkel ALGERIA)

$$m_f + m_g - m_a = 0 \quad (1)$$

$$m_g X_c - m_a X_d = 0 \quad (2)$$

We derive an expression m_g and m_a as a function of mf and refrigerant concentrations.

$$m_a = m_f \frac{X_c}{X_c - X_d} \quad (3)$$

$$m_g = m_f \frac{X_d}{X_c - X_d} \quad (4)$$

The enthalpy balance for each component exchanging heat or work with the external environment is as follows:

$$Q_g = m_7 h_7 + m_8 h_8 - m_6 h_6 \quad (5)$$

$$Q_c = m_1 (h_1 - h_7) \quad (6)$$

$$Q_e = m_1 (h_3 - h_2) \quad (7)$$

$$Q_a = m_4 h_4 - m_3 h_3 - m_{10} h_{10} \quad (8)$$

$$W_p = m_6 (h_5 - h_4) = (P_5 - P_4) \upsilon_a \quad (9)$$

The specific flow solution *FR*, which is the ratio of the mass flow of the rich solution m_a delivered by the pump and steam m_f desorbed by the generator [12] can be written:

$$FR = \frac{m_a}{m_f} = \frac{X_c}{X_c - X_d} \quad (10)$$

The difference X_c-X_d is called the range of degassing ΔX [13]

$$\Delta X = X_c - X_d \quad (11)$$

The coefficient of performance (COP) of the system is equal to [14]:

$$COP = \frac{Q_e}{Q_g + W_p} = \frac{(h_3 - h_2)}{h_7 + (FR - 1) h_8 - FR(h_6 + h_4 - h_5)} \quad (12)$$

The equations necessary for the calculation of thermodynamic and physical properties of the binary solution (LiBr/ H_2O) are given by ASHRAE [15]

4. Results and discussion

Performance of the machine given by the manufacturer and those calculated based on measurements taken during a year are compared.

4.1. Experimental investigation

Temperature measurement at different points of the installation was carried out using an infrared thermometer type (RAYTEK) Fig.1. The table.1 below summarizes the results. The experiment shows a change in the temperature of the generator and the evaporator and for this reason we will study the influence of these parameters on the system performance.

4.2. Effect of Temperatures on the Performance of the System

The evaporator temperature T_e is maintained at 5 ° C and the temperature of the absorber T_a to 38.3 ° C; increase T_c increases the value of the enthalpy h_2 Fig. 3, and decreases the flow rate *FR* and consequently decrease the coefficient of performance *COP*, following the results it can be concluded that the value of *COP* decreases with amplification T_c, elevation T_g increases *COP* for temperatures T_g lower than 90 ° C above this value *COP* begins to decline, it becomes constant for temperatures of T_g relatively high (over 95 ° C). For condensation temperature T_c equal to 43 ° C and a temperature of absorption T_a equal to 38.3 ° C and an evaporation temperature T_e from (5 ° C to 15 ° C) and a generator temperature T_g from (83 ° C to 101.6 ° C) with an efficiency of the exchanger equal 70%

Table 1. Builder and measured parameters

Parameter	Builder	Measured
T_a (°C)	38,3	39
T_e (°C)	5	12,3
T_c (°C)	43	42
T_g (°C)	101,6	83

the evaporator temperature T_e sets the value of the low pressure which increases enthalpy h_3 at the outlet of the evaporator, the coefficient of performance *COP* increases with the increase of the evaporation temperature Fig.4; if

T_e value is beyond 15 ° C *COP* is constant. We fix condenser temperature T_c at 43 ° C, the temperature of the evaporator T_e at 5 ° C, the temperature of the absorber T_a at 38.3 ° C and we varies the temperature of the generator T_g from (83 ° C to 110 ° C) with exchanger efficiency *Eff* equal 70%, if the temperature of the generator T_g increases the concentration of the weak solution increases too, which increases *FR*, the elevation of poor concentration affects positively on the enthalpy h_8 causing an increase in the amount of thermal energy required for the good functioning of the generator Fig.5. With T_c at 43 ° C, T_g equal to 101.6 ° C, T_a at 38.3 ° C and *Eff* equal to 70% , the temperature T_e affects the low pressure.
if T_e increases the concentration of the rich solution and *FR* increases too, so the amount of heat liberated from the absorber increases, on the other hand the increase of *FR* decreases the amount of heat provided to the generator.
Fig.6 show that more than temperature T_e is high the quantity Q_g is low and Q_a is max. The increase of T_g and T_e lowers the performance of the system and in particular the heat supplied to the generator Q_g Fig.5 and Fig.6. Experiments made at the unit of detergent production Henkel show that the rise of the generator and the evaporator temperature (see Table 1) had significantly lower the value of Q_g and may even caused a total shutdown of the generator Fig.7 due to the failure of the generator, as happened in the studied system.

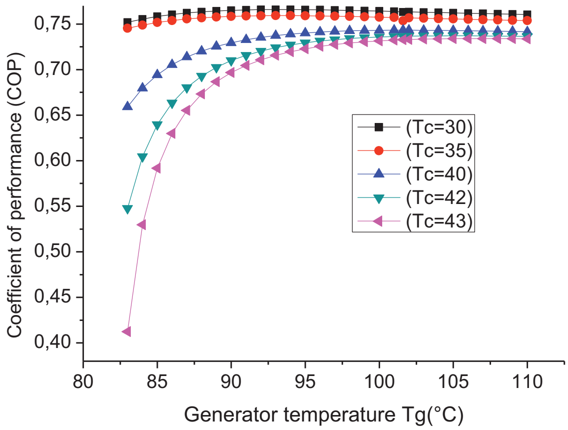

Fig. 3. Coefficient of performance versus generator temperature

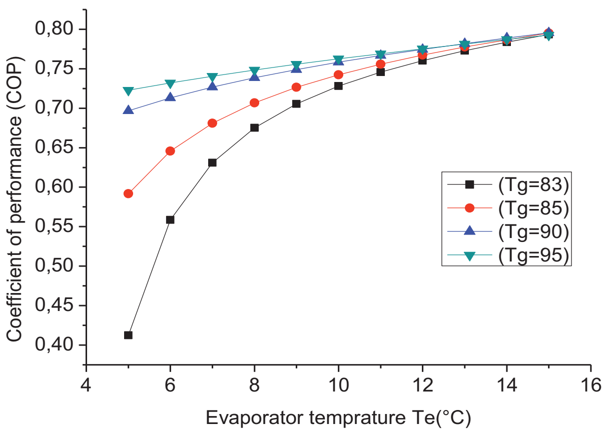

Fig. 4. Coefficient of performance versus evaporator temperature

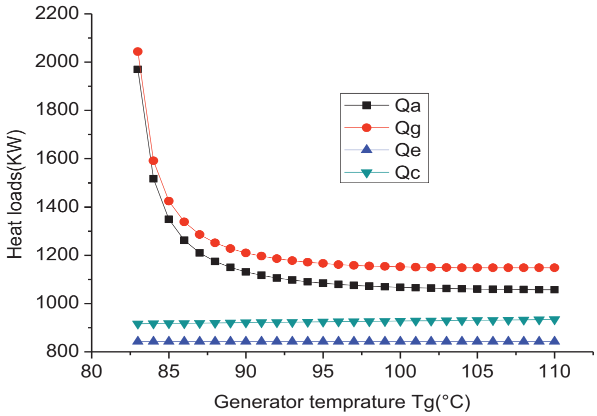

Fig. 5.Variation of heat exchanged in the each component of absorption refrigeration system versus generator temperature

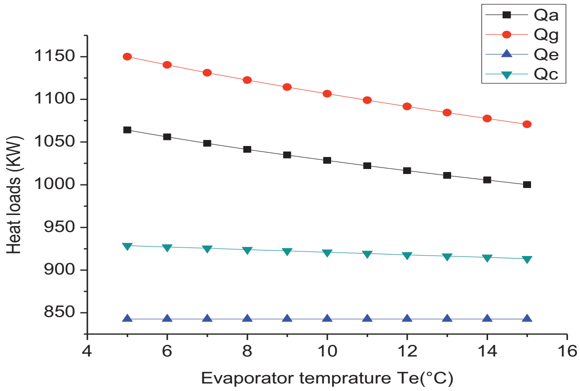

Fig. 6. Variation of heat exchanged in the each component of absorption refrigeration system versus evaporator temperature

Fig.7. the effect of increasing (Tg) (Perforated generator

4.3. Evaluation of the performance of the absorption c

The manufacture of the active ingredient is made the basis of a chemical reaction called sulfonation, the reaction is exothermic [10] The cold water from the absorption chiller is used to absorb the heat generated by this reaction, the reaction of the sulfonation is carried out in a multitubular reactor film.Greater the amount of heat absorbed is more significant sulfonation is complete. Fig.8 shows the percentage change in the sulfonation compared to the temperature at the reactor.To complete the sulfonation temperature in the reactor is between (45-50 ° C)Therefore the temperature of the cold water from the absorption chiller to be in the range (15-30 ° C) to ensure complete sulfonation [16]So even with the present regime of the absorption machine HENKEL (15-20) and despite the failures recorded in cooling towers and the solenoid valve of the steam, the machine is ugly Henkel Chelghoum functional and capable of cooling provided sulfonation reactors.

4.4. Economic evaluation of the absorption chiller unit Henkel

The energy of the absorption machine (pump solution) was compared to that of a mechanical compression (compressor).Both systems serve the same cooling loads (that of the sulfonation level unit Henkel)The operating condition of the absorption systems are those of the absorption machine T_a, Tg, T_c, T_e and temperatures of evaporation and condensation of the compression system are respectively 5 ° C and 40 ° C; R404A is used as the refrigerant for this system .The power consumed by the compressor is 17 times more than the power consumed by the solution pump regardless value of Q_e Fig.9 We give here the additional value for the use of a mechanical compression system. We can clearly see that a mechanical compression system can replace an absorption system only, the power consumption will be amplified further ahead in time, and therefore an additional expense will be added to the initial energy cost Fig.10.

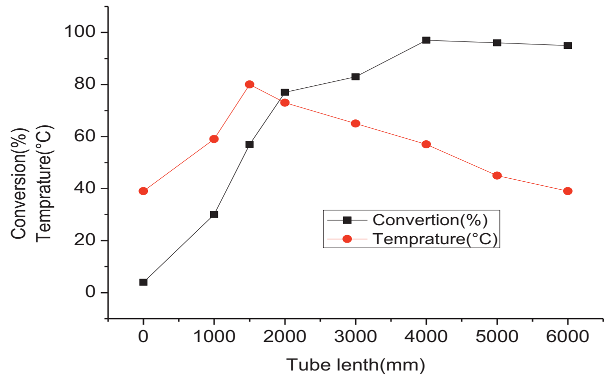

Fig.8. temperature and conversion rate of the sulfonation versus tube length

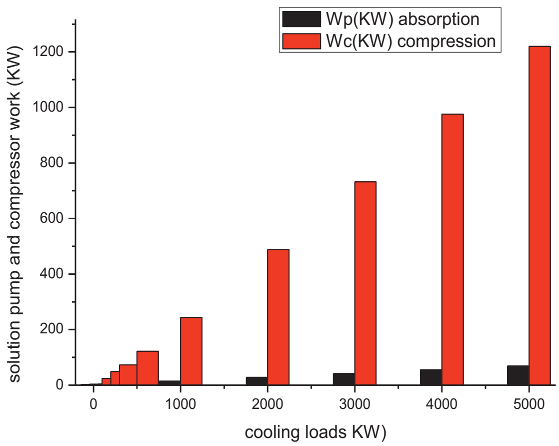

Fig.9. Comparison between the energy consumption of an absorption system and mechanical compression machine

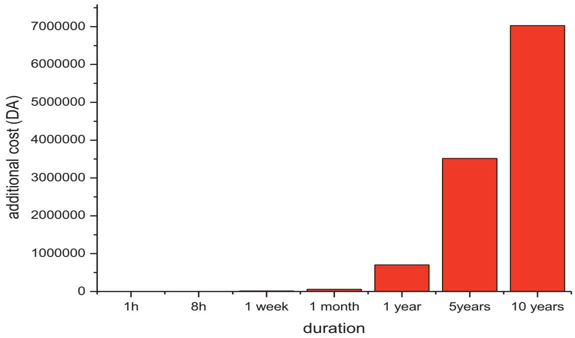

Fig.10. additional coast value depending versus the duration

5. Conclusion

This paper reports on experimental study to characterize the process of producing cold using an absorption machine in an industrial unit for the production of detergent. Using the FORTRAN program we analysed the effect of temperature on the performance and thermal loads of the system. This program allows drawing different curves characteristic of the refrigerating machine studied in terms of temperature influence. After comparison of specific and experimental variables we have observed: The influence of temperature variation on the performance and thermal loads is proportional to the variation of each temperature.

For the two situations, namely, the situation in the initial state characterized by the operation parameters of the constructor and the current state quantities (measured parameters).Temperatures T_e and T_g have the most influence on the system, they also suffered for (34 years) the most change. cooling towers are the partial cause of these changes, in addition to the huge amount of data on incidents in these machines for a period of 12 years the most serious, according to some studies usually involve the generator (perforation lines see fig.7), Despite that the machine remains competitive facilities to mechanical compression. In addition to the advantages mentioned above, we can also add the recovery and recycling of heat energy by product (phenomena of sulfonation) investment efficiency and saving energy despite high cooling loads.

Références

[1] IIR, International Institute Of Refrigeration,"Aperçu sur L'histoire du Froid".
[2] Ballestra, M. and Triberti, D. US Patent 713401 Muhsin Kilic, Omer Kaynakli, "Theoretical Second law-based thermodynamic analysis of water-lithium bromide absorption refrigeration system", July 2004.
[3] Warmepumpen, Valkanverlag, Glaser. Bases thermodynamiques des pompes à chaleur à absorption, H 1987.
[4] Muhsin Kilic, Omer Kaynakli, "Theoretical Second law-based thermodynamic analysis of water-lithium bromide absorption refrigeration system", July 2004.
[5] Romero RJ, Rivera W, Gracia J, Best R, "Theoretical comparison of performance of an absorption heat pump system for cooling and heating operating with an aqueous ternary hydroxide and water/ lithium bromide", Appl Therm Eng 2001.
[6] Saravanan R, Maiya MP, "Thermodynamic comparison of waterbased working fluidcombinations for a vapor absorption refrigeration system", Appl Therm Eng 1998.
[7] ASHRAE, "Handbook of Fundamentals", Atlanta, 1997.
[8] Adami, I. Design criteria, mechanical features, advantage and performance of multitube falling film sulphonation reactor.
[9] Kaynakli O, Kilic M. Theoretical study on the effect of operating conditions on performance of absorption refrigeration system. Energy Convers Manage 2007;48:599–607.
[10] Sun DW. NH3–LiNO3 and NH3–NaSCN absorption refrigeration system Comparison of NH3–H2O. Energy Convers Manage 1998;39:358–67.
[11] S. Aphornratana, I.W. Eames, Thermodymic analysis of absorption refrigeration cycles using the second law of thermodynamics method, International Journal of Refrigeration 18 (4) (1995) 244–252.
[12] M. de Vega, J.A. Almendros-Ibanez, G. Ruiz, Performance of a LiBr–water absorption chiller operating with plate heat exchangers, Energy Conversion and Management 47 (18–19) (2006) 3393–3407.
[13] Prasad, M., I.I.F.-I.I.R., Commission Bl, B2, El, E2, Mons, Belgium, 1980, p. 265.
[14] Prasad, M. and Gupta, V. K., Solar energy symposium, Baghdad, Iraq, 1981.
[15] Alizadeh, S., Bahar, F. and Geoola, Solar Energy, 1919, 22, 149-154.
[16] Shiran, Y., Shitzer, A. and Degani, D., Solar Energy, 1982, 29, 43-54.